ON WEATHER CHANGES FROM DAY TO DAY

By HENRYK ARCTOWSKI

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During the years 1898 and 1899, while making observations on board the *Belgica,* I frequently noticed an intimate relation between the successions of cloud sheets and the waves of pressure registered by the barograph.

There, in the Antarctic, in approximately 70° latitude, the mean duration of waves of at least 5 mm. amplitude was 126 hours, or 5.25 days. The pressure waves observed about 10 years later, in McMurdo Sound and Framheim, 8° or 9° farther south, were longer, since the figures given by Simpson are 6.33 and 6.79 days. Going northward, on the contrary, they become shorter: 3.79 days on the South Orkneys, in 61°; and 2.87 days on Kerguelen Island in 49° S. latitude. Thus, twice as many waves occur during the year, for a difference of 30° latitude, in the Southern Hemisphere.

These facts justify the question: Do the Antarctic pressure waves split in two, or do the figures for latitude 49° correspond to intercrossings of waves of different origin?

In lower latitudes the ups and downs of the barometer are greatly reduced in amplitude, and the well-pronounced diurnal variation excludes the use of barograms for the counting of waves.

Taking the 8 a. m. observations of Lorenço Marques, 25°58′ S. latitude, all waves of at least 2.5 mm. amplitude noted during 1910–19 gave a mean duration of 6.6 days. To obtain a figure for Batavia (6°11′ S.) comparable with that for 79° S., ups and downs of not less than 0.5 mm. had to be counted; the mean for the 10 years considered is 7.5 days. In Greenland and Iceland, taking 5 mm. as the least amplitude, the means of the years 1910–19 are 6.9 days for Upernivik, 6.5 for Godthab, and 6.5 for Vestmannö, figures similar to those for the Antarctic.

Are the equatorial waves, of small amplitude, only an attenuation of those observed in polar regions? Maps are necessary to answer this question.

For another reason, also, day-to-day world maps of isallobars should be drawn, and continued, if possible, year after year.

The monthly values of the wave lengths observed in Warsaw, for the years 1869 to 1903, have been published by Merecki.[1] Overlapping means of these data give a most interesting diagram (fig. 1) showing a variation broken by discontinuities.[2]

The highest and the lowest durations are 6.7 and 4.8 days for the means of 12 consecutive months. We must suppose, therefore, world variations of the duration or length of the waves, or displacements of the centers of most frequent intercrossings of waves of different origin.

The researches by Ekholm on maps of isallobars are well known.[3] Connected areas of increase and decrease of pressure on the map show the extent of a wave. Ekholm has given no name to the pressure waves as seen on isallobaric maps; I have proposed to apply the name *anoterons* to the areas of positive pressure differences observed from day to day at a given hour, and *katoterons* to those of pressure decrease.

The pressure wave may, therefore, be called a *teron,* or a *baroteron.* The barograms show that often we should also take into consideration *brachyterons,* or waves of short duration.

North America baroterons; December 1935.—The weather maps of Canada, the United States and Mexico, from December 2 to 7, 1935, have been used to draw isallobars (figs. 2, 4, 6, 8, 10). The differences from date to date are given in hundredths of an inch.[4]

The first map, December 3 shows, a katoteron extending from Quebec, across the States, to La Paz at the southern end of the Californian peninsula (fig. 2). Differences of −38 are observed at Parry Sound, Ontario, and Davenport, Iowa. But from Aklavik, west of the mouth of the Mackenzie River, the axis of another katoteron extends in a southeast direction, to Helena, Mont. Thus, the intercrossing of terons cannot be doubted.

During the day the northeast–southwest katoteron moved eastward. On the 4th (fig. 4) it extends from Newfoundland and Labrador, along the Atlantic coast and down across Mexico, to the Pacific. The eastward displacement continues. However, the northwest–southeast axis of the V-shaped katoteron of the 5th (fig. 6) has on the 6th (fig. 8) become an all-dominating axis of negative values extending from Alaska to the Yucatan peninsula.

On the 7th (fig. 10) the displacement continues, but with a rotary movement; now the axis of the katoteron extends almost north-south, and similarly with the eastern anoteron.

A comparison with the weather maps shows, first of all, that terons move faster than LOWS and HIGHS. This fact is well known; and the deduction that the changes of pressure from day to day are primarily due to displacements of air masses at higher atmospheric levels has been developed by Ekholm, Ficker, and others.

On the other hand, the intercrossing of terons could have been deduced a priori from the wave frequency referred to before, fewer waves per unit of time in the Antarctic than in the Sub-Antarctic regions: Let us say, Framhein, 6; Belgica, 5; South Orkneys, 4; and Kerguelen, 3 days.

Naturally, one may be led to ask whether LOWS and HIGHS may not be due, in many instances if not always, to the intercrossings of katoterons and anoterons? This question should be considered with great care, since it implies that cold and warm fronts, and the shifting of wind directions, observed at the bottom of the atmosphere are the consequences, and not the causes, of the pressure changes registered on weather maps. However, the study of thermoterons justifies the view that the formation of LOWS may be the consequence of intercrossings of katoterons.

North American thermoterons: December 1935.—For Europe, maps of isallotherms have been published by Defant,[5] who found that generally the areas of increase of pressure correspond to those of decrease of temperature.

Schedler has shown that these conditions relate to the lower atmosphere, up to about 3 km., and to the substratosphere, between 10 and 12 km. of altitude; whereas between 3 and 9 km. an increase of temperature corresponds to an increase of pressure.[6] This led Schedler, Defant, and others to the conclusion that the pressure changes observed at the earth's surface are a direct reper-

[1] R. Merecki: Klimatologia ziem polskich, p. 200. Warszawa 1914.
[2] Inst. Geoph. Met. Univ. Lwow, Comm. v. 8, p. 174. Lwow 1936.
[3] Met. Zeit. Hann-Band, p. 288, Braunschweig 1906.

[4] Isallobaric maps have been regularly used by the U. S. Weather Bureau in their forecast work since 1872, although they have not been published and little has been written concerning them. See MONTHLY WEATHER REVIEW, March 1916, p. 132: On Pressure Change Charts, by Edward H. Bowie. Vol. 44.
[5] A. Defant: Wetter und Wettervorhersage, 2 Aufl., p. 159. Leipzig 1926.
[6] A. Schedler: Beitr. z. Phys. d. freien Atm., v. 7, p. 88. München 1917.

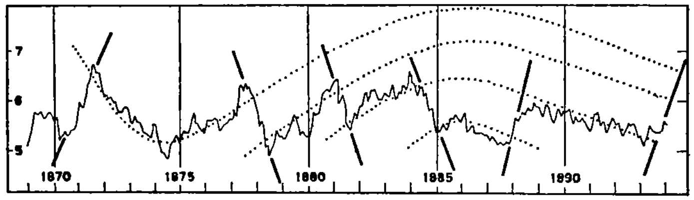


FIGURE 1.—Pressure wave-length variation in Warsaw. Consecutive 12-monthly means.

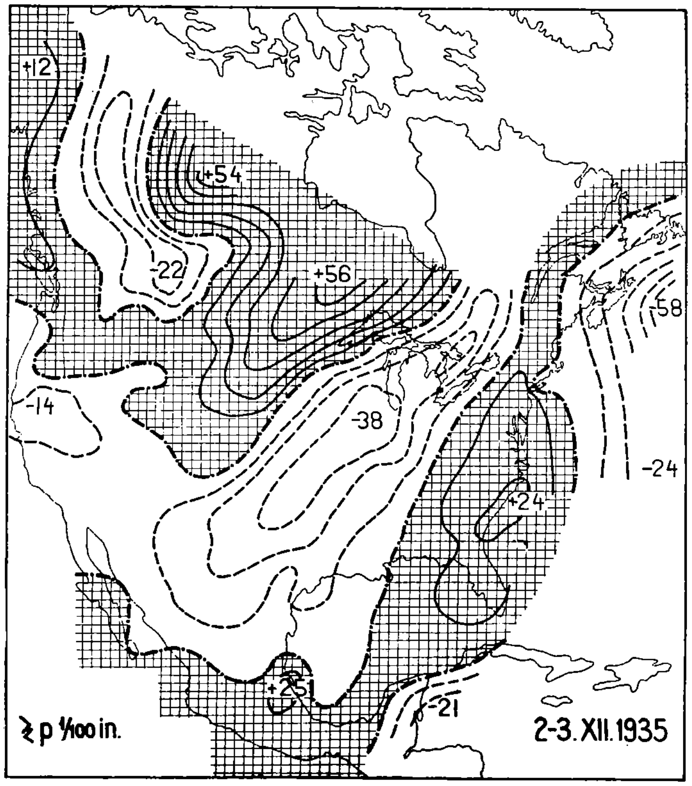


FIGURE 2.—Isallobars for December 3, 1935, over North America.

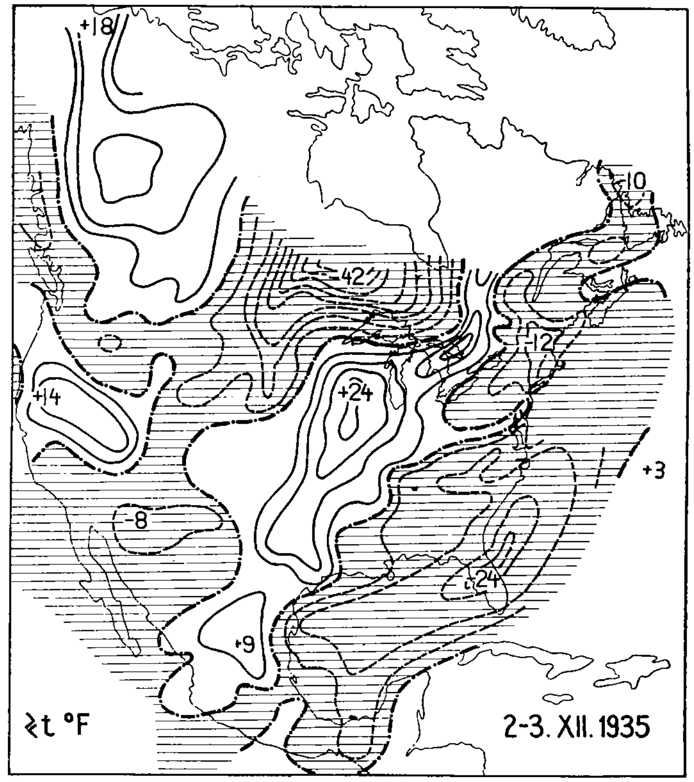


FIGURE 3.—Isallotherms for December 3, 1935, over North America.

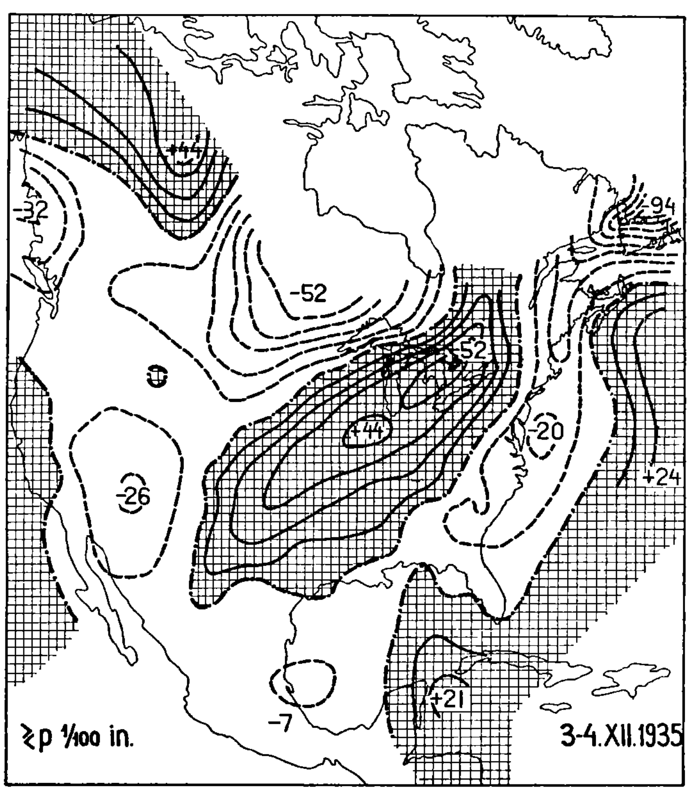


FIGURE 4.—Isallobars for December 4, 1935, over North America.

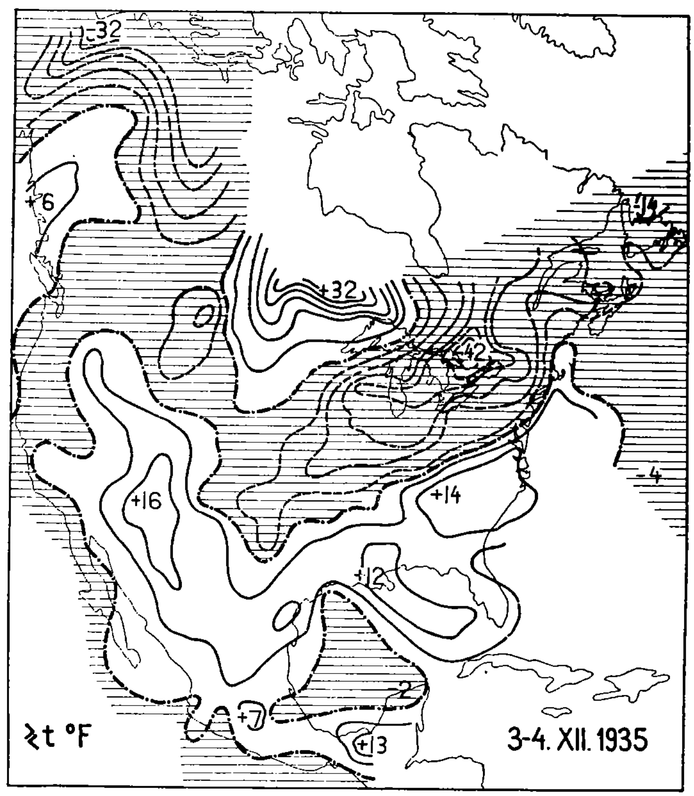


FIGURE 5.—Isallotherms for December 4, 1935, over North America.

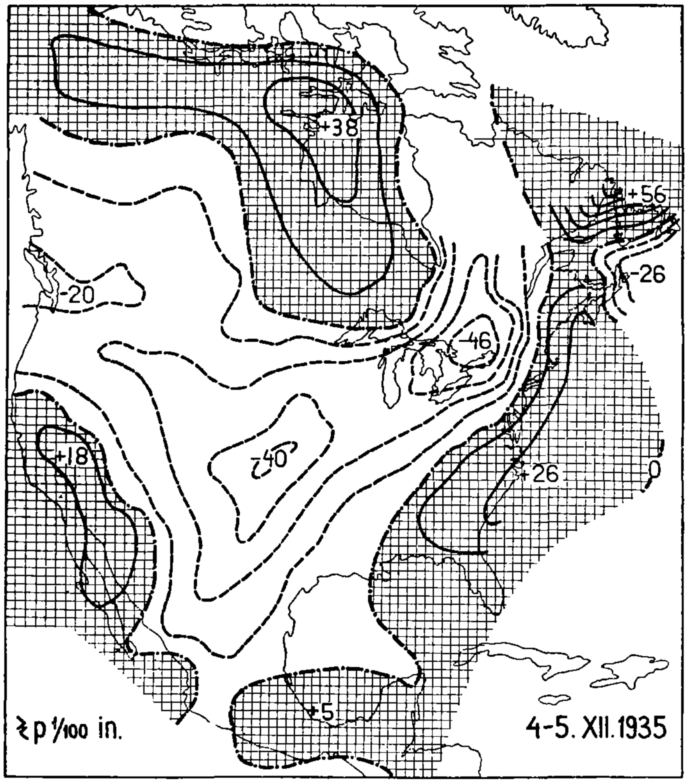


FIGURE 6.—Isallobars for December 5, 1935, over North America.

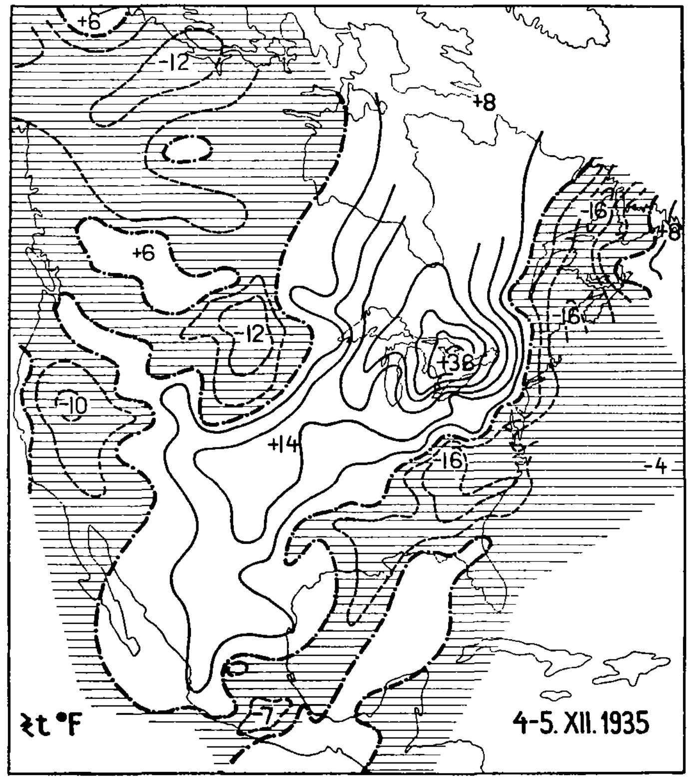


FIGURE 7.—Isallotherms for December 5, 1935, over North America.

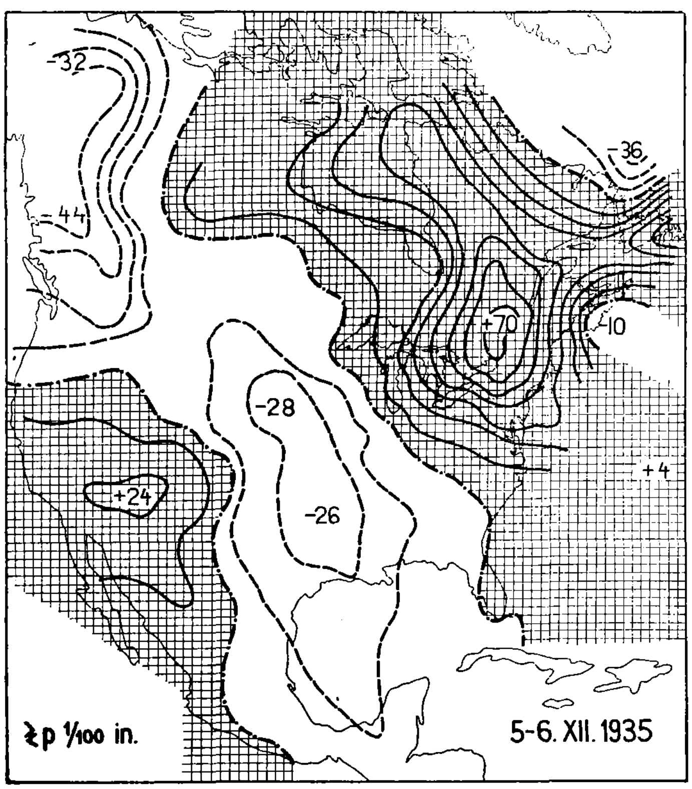


FIGURE 8.—Isallobars for December 6, 1935, over North America.

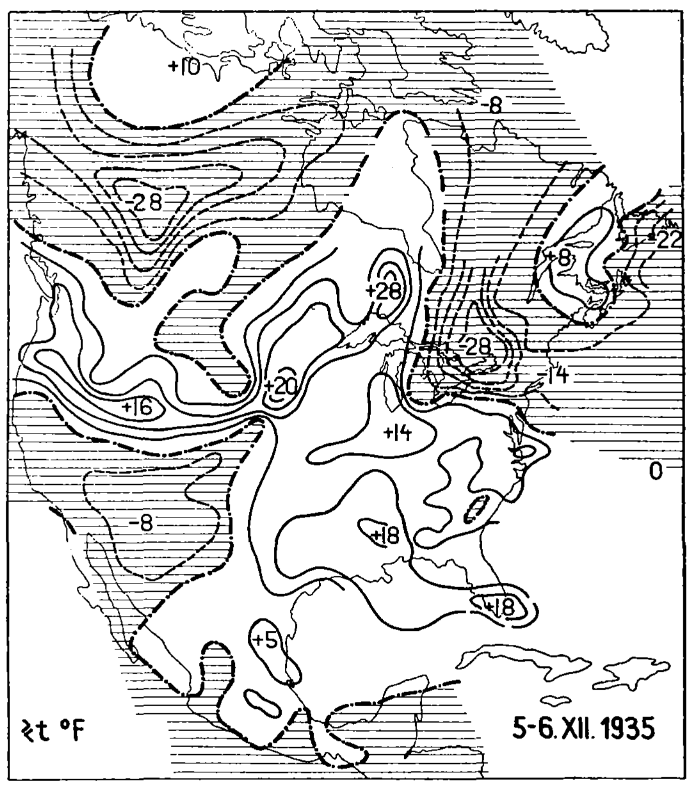


FIGURE 9.—Isallotherms for December 6, 1935, over North America.

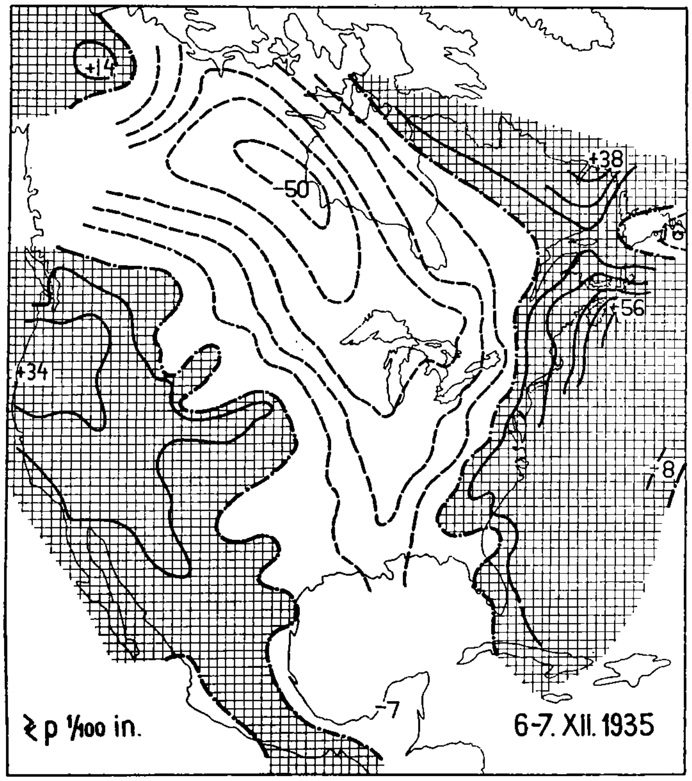


FIGURE 10.—Isallobars for December 7, 1935, over North America.

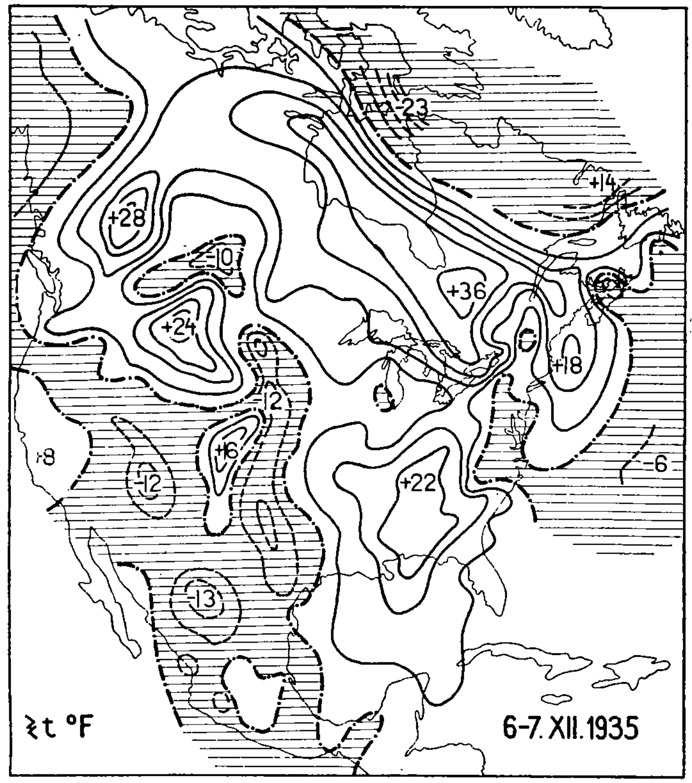


FIGURE 11.—Isallotherms for December 7, 1935, over North America.

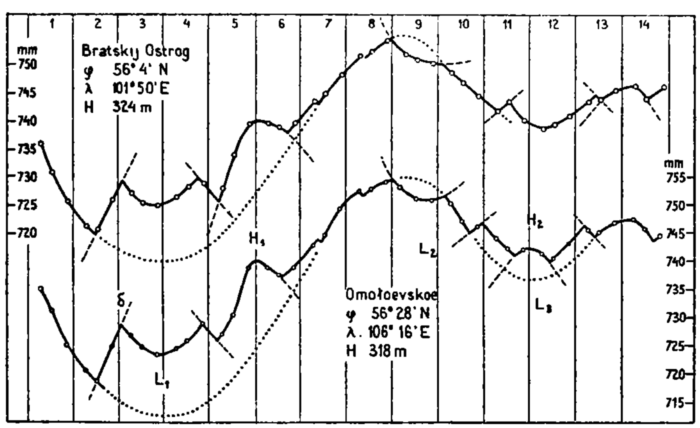


FIGURE 12.—Pressures observed January 1-14, at Bratskii Ostrog and Omoloevskoe.

cussion of the temperature changes observed in the substratosphere.

Admitting that in the United States, especially during the winter months, temperature changes from day to day may depend upon changes of wind direction, maps of thermoterons should be carefully compared with the weather maps; such comparisons show at once that many striking temperature changes may be easily explained. (See figs. 3, 5, 7, 9, 11.)

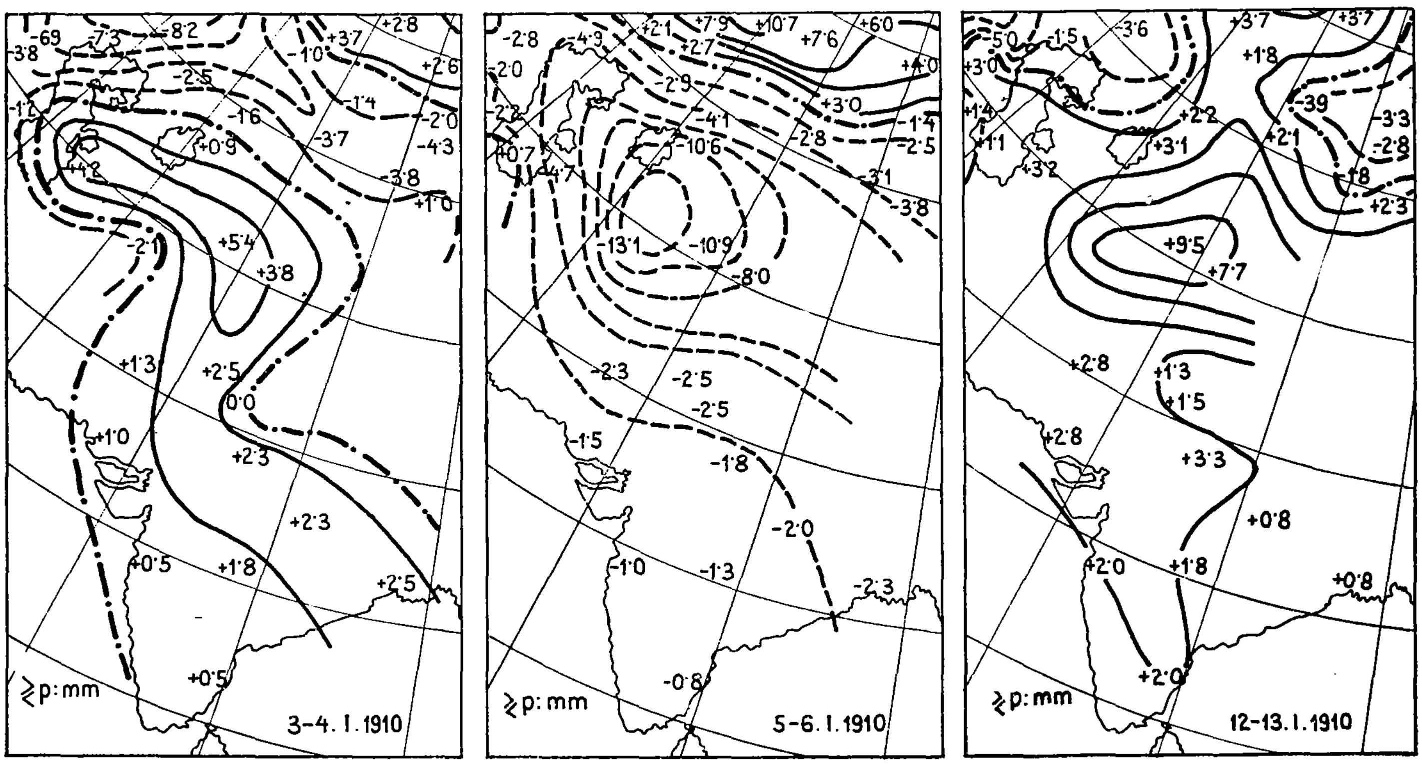
For example, on the map of December 3 (fig. 3), we notice that at Tampa, Fla., a decrease of 24° F. occurred; the weather maps will show that, under the influence of a displacement of the center of a HIGH from Fort Smith, Ark., to Asheville, N. C., a strong wind was blowing in Tampa from the south on the 2d, and from the north on the 3d. Farther north, at Cape Hatteras, no change of wind direction occurred, and the morning temperature was 12° lower on the 3d perhaps because the wind continued to blow from the north for more than 24 hours. A decrease of 10° at Belle Isle (between the northern Cape of Newfoundland and the coast of Labrador) can again be easily explained: southwest wind the 2d, north on the 3d.

Russian data: January 1910.—The barometric observations at the Russian stations for 7, 13, and 21 o'clock (local time) have been used to draw maps of the differences from day to day. The same has been done for the morning observations in western Europe, Iceland, the Azores, and North America.

At the longitude of Irkoutsk the clock is 7 hours in advance of Greenwich time. But the deformations of the isallobars, due to this fact, are progressive, going east or west; and since day after day they are similar, the maps are comparable. Making the comparisons, step by step, it seems that the 90 Russian maps for January 1910 should have been sufficient to show the progressive displacements of the pressure waves and, in the case of intercrossings, to permit of explaining the deformations or discontinuities of baroterons. However, this is not always the case, because the number of observational points, especially in Siberia, is not sufficient and because a detailed study of barograms is often absolutely necessary to understand the changes shown on the maps.

Let us compare the diagrams for Bratskii Ostrog and Omoloewskoe from January 1 to 14 (fig. 12). It becomes evident at once that errors might result from considering differences of not less than 5 mm. of increase and decrease of pressure to be waves.

At Omoloewskoe the differences of about 8 mm., between the 2d and the 3d, is due to a discontinuity in the variation, and not to a wave. L is an uplifted minimum, L_2 a depressed maximum, and L_3 again a slightly uplifted minimum. If L_3 were a minimum corresponding to L, then we should have to deal with a wave of 8 days; but at L_3 a maximum H_2 interferes, which is the direct result of a HIGH, whereas at Bratskii Ostrog the minimum is simply uplifted. H_1 and H_2 are only 6 days apart. These two maxima may belong to an intercrossing wave.



FIGURES 13, 14, and 15.—Isallobars for Turkestan and India, January 4, 6, and 13, 1910. (Differences of pressure in mm.)

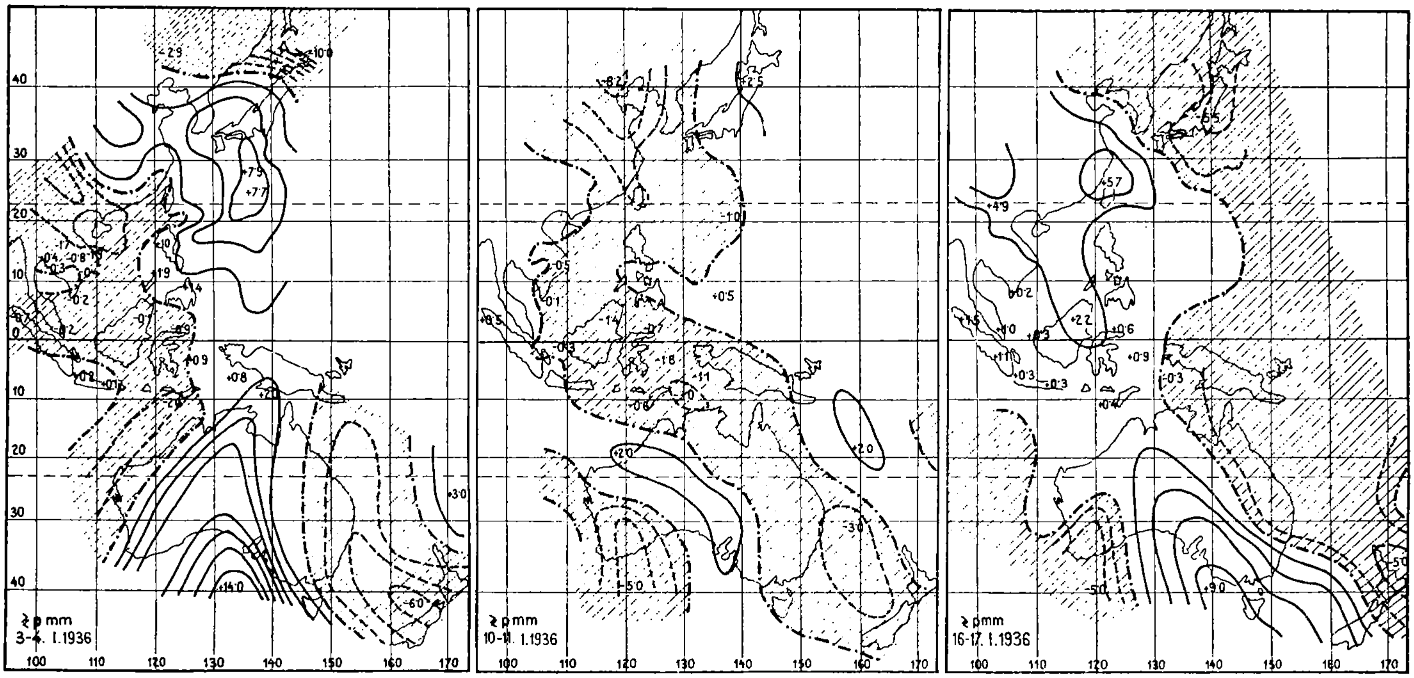
Of two intercrossing wave motions, one or both of them may be composed of a succession of shorter waves. Discontinuities of cloudiness are often shown by Al.-Cu.; and the statoscope registers the small amplitudes of the discontinuities of the barometric curve going up or down.

The progress of the waves may be slow in one case, less slow in the other; they may involve different levels of the atmosphere. The progress of a teron may be temporarily delayed at one end, accelerated at the other end.

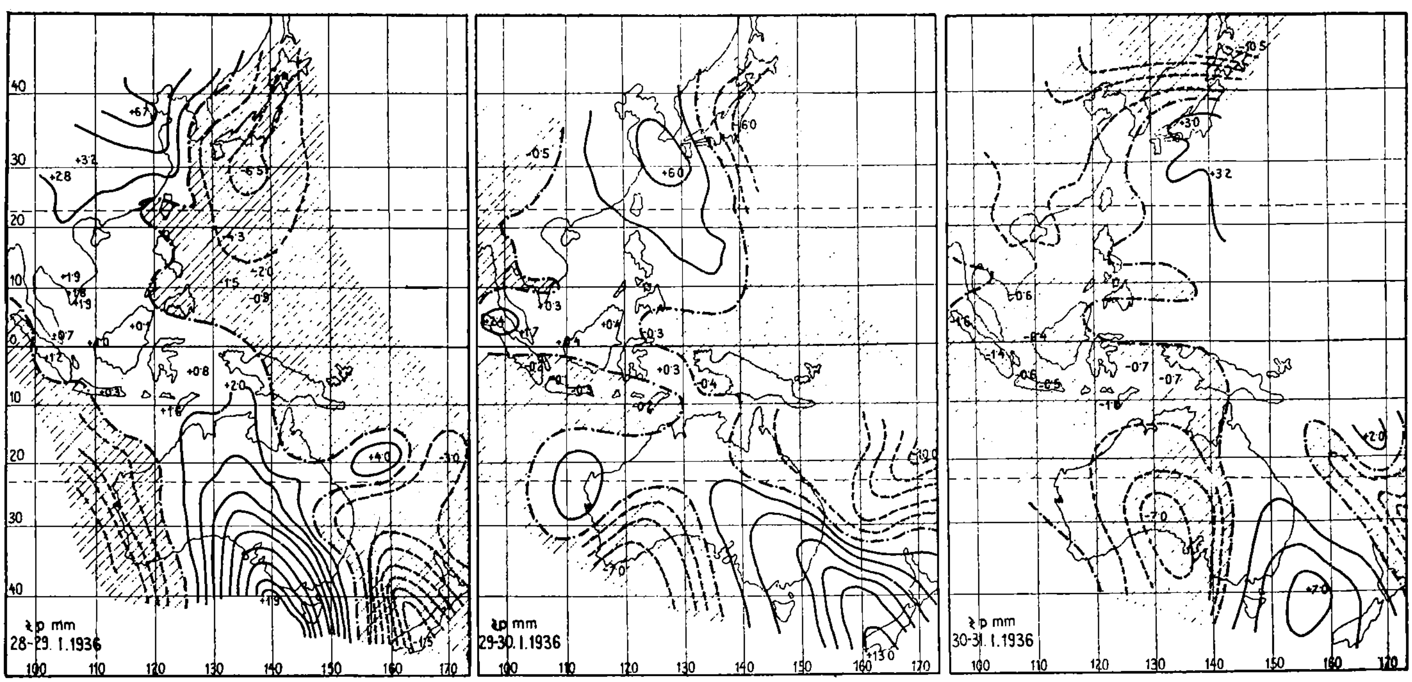
The pressures registered at a given station must be a resultant of the pressures of different air masses, all in motion; the succession of LOWS and HIGHS, or of terons, can never be regular, and it is useless to try to simplify things by theoretical considerations.

The Russian maps of isallobars are instructive mainly because they show plainly the crossings of baroterons, irregularities of progress, forward and backward displacements and, above all, the fact that discontinuities of variations should exist simply because every excessive Asiatic pressure maximum goes down by steps, due to European or Arctic reactions.

the Balkans, Cyprus, Palestine, and Transcaucasia. Along the 25th meridian the axis of the anoteron of increasing pressure has been shifted north of the Black Sea. A radical change of displacement and direction of the teron is in progress.



FIGURES 16, 17, and 18.—Isallobars for China and Australia for January 4, 11, and 17, 1936. (Differences of pressure in mm.)



FIGURES 19, 20, and 21.—Isallobars for China and Australia for January 29–31, 1926. (Differences of pressure in mm.)

Across Europe and Asia, we may observe anoterons and katoterons extending west–east and moving south or sometimes north. The maps of January 6, 7, and 8, 1910, may be taken as examples. On the map of the 8th there is an axis of negative values extending from Iceland over Scotland to Poland. On the 9th the barometer also falls in

Another selection of maps shows north to south waves moving from west to east. A fall of pressure of 30 mm. from the 23d to the 24th, observed in England, belongs to a katoteron extending from the Arctic circle at least as far south as Madeira. On the 25th the axis of the katoteron goes from the Arctic regions, through Lapland, Central

Europe and across the Alps and the Mediterranean, to Algeria and the Sahara. On the 26th, a narrow axis of negative values extends from Scandinavia to Greece. By the 27th it moved farther east.

It should be useless to describe these maps in detail. The barograms of many stations should be compared with the maps in order to make an interpretation of the details of the observed pressure variations. The study of the distribution of rainfall should be the principal purpose of such researches.

Pressure changes in Turkestan and India.—North of the Pamir and south of the Himalaya Mountains the pressure changes from day to day are often similar. Isallobars for India are related to those of the Turkestan and Siberia. (See figs. 13, 14, 15.)

The most important wall of mountains in the world, separating Asiatic Russia from India, does not influence the distribution and displacements of terons—just as if the lower atmospheric strata (below an altitude of about 5,000 m.) were affected mainly by the pressure changes occurring above. At least this is true for the baroterons during January 1910. The anoteron on the 13th, extending from 70° to 10° latitude, from Novaiia Zemla to Ceylon, may serve as example (fig. 15).

Detailed isallobaric maps of India have also been drawn for January 1934 and October 1935, making use of all the 8 o'clock data of the daily weather maps. In most cases the changes of pressure from day to day, as shown on these maps, must depend on those of Turkestan and central Asia.

The maps from October 13 to 23 are of particular interest because of a tropical cyclone that crossed the Decan. The isallobaric map of the 16th and 17th shows an isolated katoteron north of Ceylon, and also negative values in the Punjab as far as the northwest frontier. The decrease on the 18th was highest at Madras, and at the same time the katoteron of the Punjab spread out over the central Provinces. The map of differences for the 19th shows the entire area of India occupied by negative values. From then on, the barometer continued to fall until the 23d in northern India and Burma.

This example leads to many questions concerning the ultimate relations between tropical cyclones and terons.

China and Australia: January 1936.—In order to draw isallobaric maps extending from the 40th parallel north to the 40th south, pressure data from 11 stations in the Dutch Indies have been added to those of the synoptic charts of Indochina, Hong Kong, and Australia. These

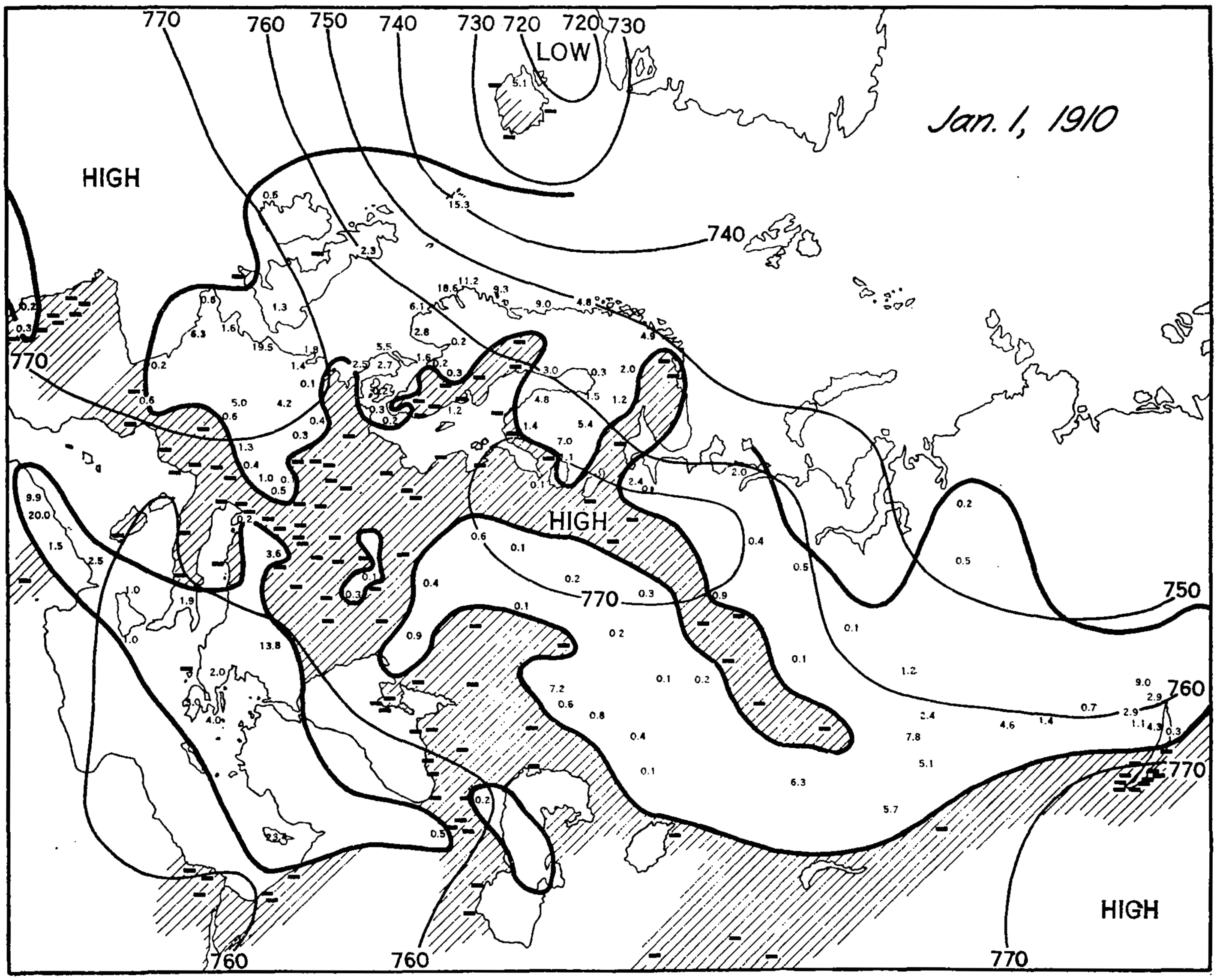


FIGURE 22.—Precipitation areas, January 1, 1910. Heavy dashes indicate observed zero precipitation (shaded area).

maps show that anoterons and katoterons often extend across the Equator from one hemisphere to the other.

The maps of pressure differences of the 4th, the 11th, and the 17th (figs. 16, 17, 18), and those of the 29th, 30th, and 31st (figs. 19, 20, 21) may serve as examples.

During the year 1882 a total rainfall of 2,460 mm. was observed in Batavia, while for 1891 it was 1,166 mm.—more than double for a year of maximum than during a year of minimum of rainfall.

Since the frequencies of pressure waves (of 5 or more mm. amplitude) observed in Warsaw differ greatly from year to year, we may admit, a priori, important changes of the mean amplitudes and frequencies of baroterons, all over the world. Simultaneity of maxima or minima is not to be expected.

If any relation exists between the frequency and quantity of rainfall and the frequency and amplitude of baroterons, it is possible that such a relation will be best observed in equatorial regions. Investigations of the phenomena in Batavia gave promising results.

Rainfall and baroterons: January 1910.—Although it seemed improbable that any simple relation between katoterons and diurnal rainfall areas should exist, maps were drawn for January 1910, using all available Russian data and those of a number of other European stations.

These maps were compared with the pressure maps of the Northern Hemisphere published by Exner,[7] and with those of the isallobars described before. See figures 22, 23, 24.

It is evident that, in general, rainfall of a given date occurs only during some particular hours of that day; and there are different kinds of rainfall. Comparisons should therefore be made with pressure changes for the hours during which rain fell, and for each kind of precipitation separately.

The rainfall areas, however, disagree with the distribution of pressure in so many cases and in such a striking manner, and so often do not occur where they should according to theory, that a detailed study of the rainfall maps seems desirable.

For example, the map of January 1 (fig. 22) shows three wide strips of rainfall, extending west to east, one from the

[7] Felix M. Exner: Karten der atmosphärischen Zirkulation auf der Nördlichen Halbkugel vom 1. Januar bis 31 März 1910. Wien 1929.

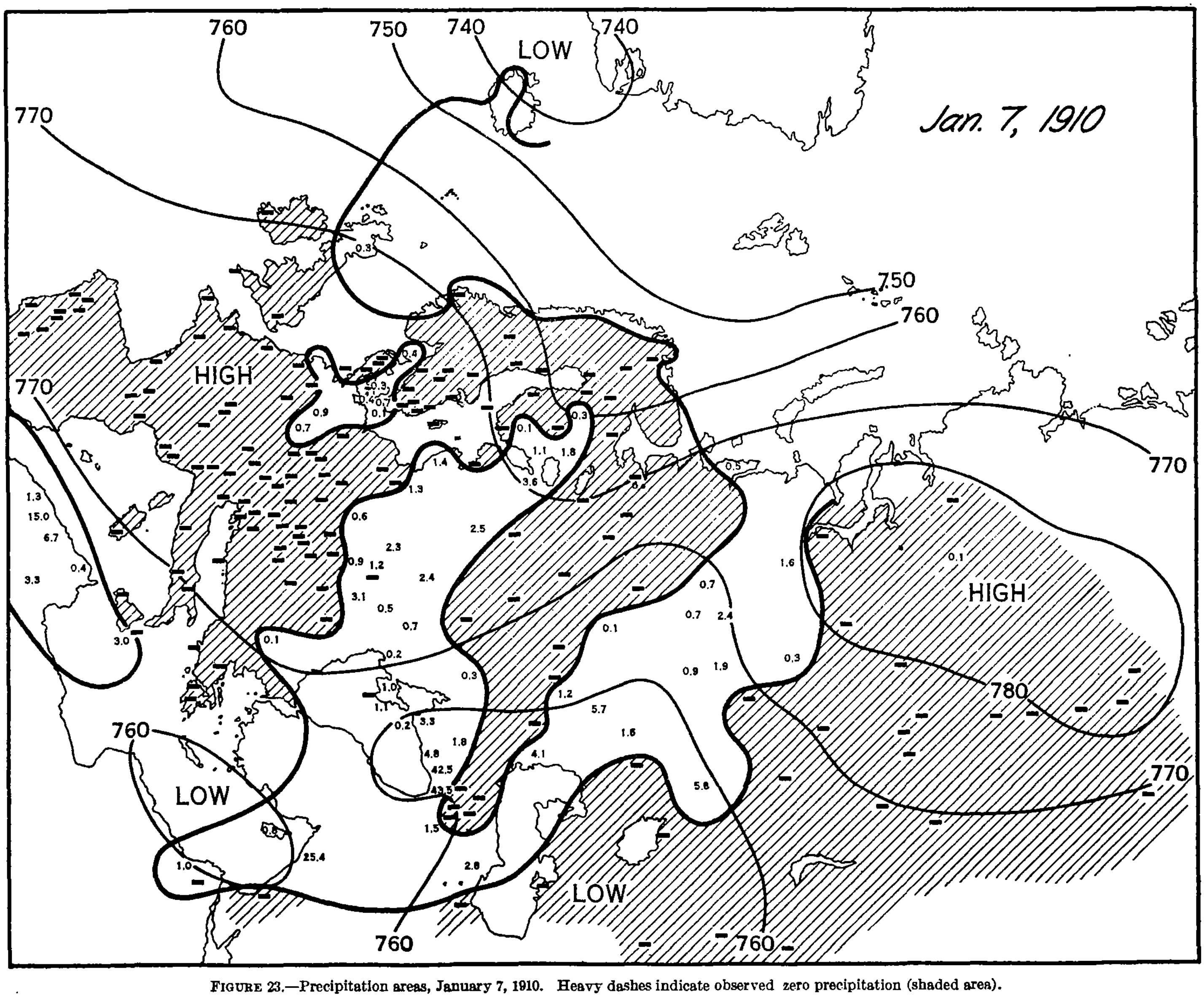


FIGURE 23.—Precipitation areas, January 7, 1910. Heavy dashes indicate observed zero precipitation (shaded area).

White Sea into Arctic Siberia, the second along approximately the 55th parallel from 30° to 115° longitude east, the third from Algeria across Sicily and Greece to Cyprus. Neither isobars nor isallobars will explain this fact.

The map of the 7th (fig. 23) may be taken as another characteristic example of which a study should be made. It shows one wide strip of recorded rainfall from Finland down to the Black Sea, and another from Novaiia Zemla down to the Caspian Sea, both going across the continental axis of high pressure of that date.

Most of the rainfall maps show such strips of precipitation, more or less independent of the pressure distribution, but offering in a sufficient number of cases enough anologies with the isallobaric maps to tempt one to speak of ombroterons.

The 14th (fig. 24) may be taken as an example. The high-pressure areas of central Asia and of the Azores are connected. Two LOW centers, one near Iceland and the other on the sea of Kara, make the isobars extend in a general east-west direction; while across Europe and Asia, in a north–south direction, across the continental axis of high pressure, five strips without rainfall, and five elongated embroterons, just like pressure waves, are recorded. The rainfall area extending from the North Cape to Greece is connected with a west Mediterranean-Black Sea rainfall axis.

Comparison with the map of isallobars supports the hypothesis of correlation.

As has been seen on the curve of Omoloevskoe discussed before, isallobaric maps based on intervals less than 24 hours should show pressure differences due to discontinuities of variations. This leads to the working hypothesis that ombroterons are the product of reactions of fronts of discontinuity in baroteronic air mass displacements in the lower atmosphere.

The comparison of the maps of isallobars show tendencies toward increasing or decreasing anoterons or katoterons during a succession of days. This fact must be due to transport of air masses over periods of successive days.

Maps of differences of 10-day means, as well as of monthly means, show these world displacements of pressure excesses or deficits quite well. The same may be said about the annual means and the means of lustra of years.

Abnormal seasons of a given year, or the anomalies of a month or two, may therefore depend upon certain tendencies of climatic variations.

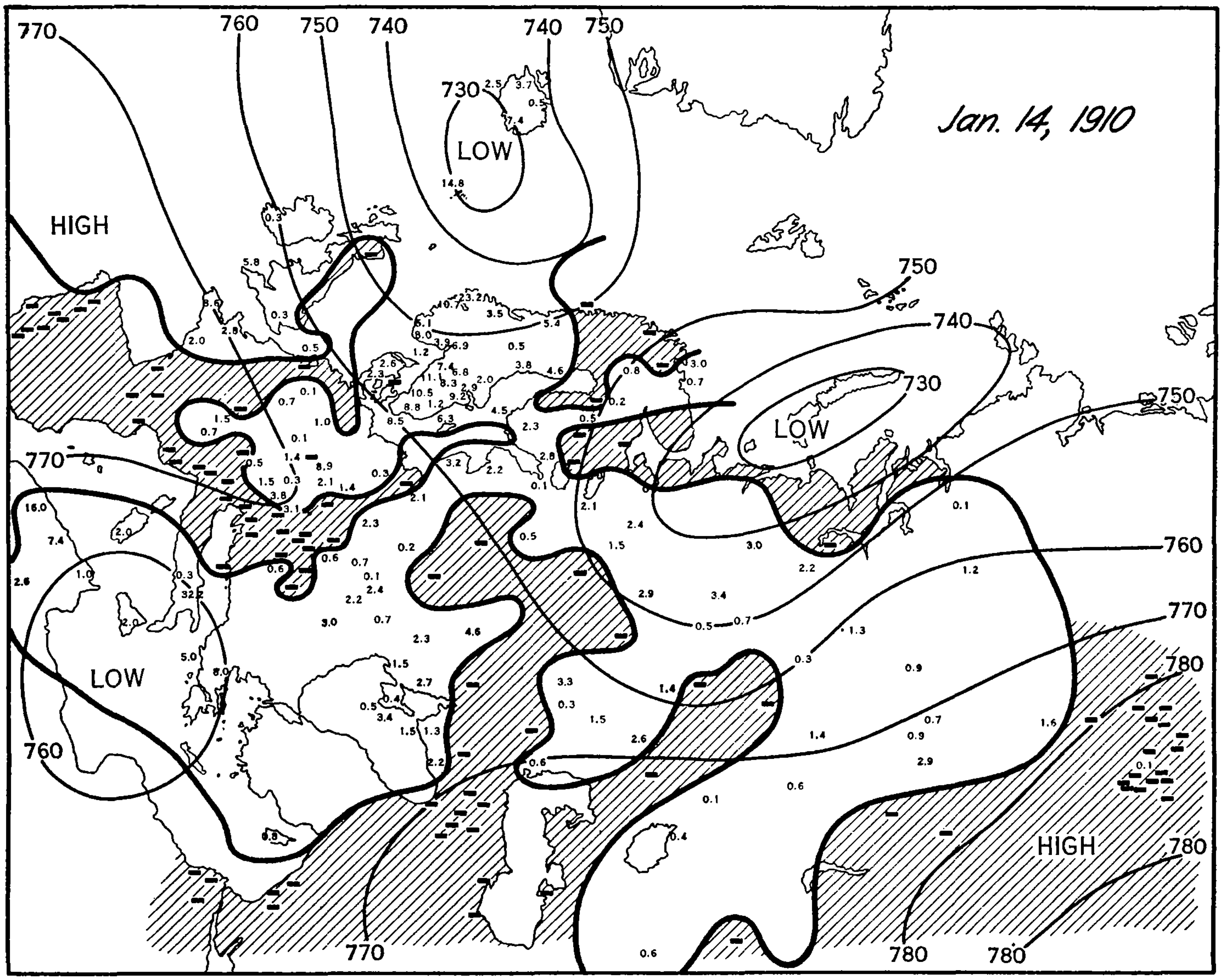


FIGURE 24.—Precipitation areas, January 14, 1910. Heavy dashes indicate observed zero precipitation (shaded area).